# “I’m Melting!”

| Preparation Time: | Easy-to-do | Moderate | **Extensive** |
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6.AIR.6

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|---|---|
| **Grade:** | 6 – 8 |
| **Focus:** | Acid rain |
| **Subject:** | Science, Math, Geography |
| **Materials:** | See list below |
| **Teaching Time:** | Several class periods |
| **Vocabulary:** | Dry fallout |

**Learning Objective**
Students will determine how acidity and pH relate to acid rain and its effects on different materials.

**Background**
Acid rain is caused by the conversion of sulfur oxides and nitrogen oxides in the upper atmosphere into sulfuric and nitric acid. These acids are formed when the oxides combine with moisture in the atmosphere. They then fall to earth during precipitation in the form of rain, snow, fog and “**dry fallout**.”

The major sources of sulfur oxides are coal-burning power plants and industrial boilers. Nitrogen oxides also come from coal-fired boilers and automobiles. In North America, the areas most sensitive to acid rain are those where acid rain falls on shallow soils and granite bedrock. Lakes that lack the ability to buffer, or neutralize, the acid are also in danger.

Acid rain has many damaging effects including killing animal life in lakes and harming vegetation. This produces a threat to people as well. In addition, many buildings and monuments made from granite and limestone are “eaten away” over time by acid rain.

This is not a new problem and there are some solutions to the acid rain problem. While this used to be a local problem in areas downwind of power plants and industrial facilities, the use of tall smokestacks sends the pollutants high into the atmosphere where weather patterns spread the pollutants over much of North America. In fact, a portion of South Carolina’s air pollutants are from the Midwest and Ohio Valley regions. Coupled with the propensity for stagnant weather patterns over much of the state in the summer months, and you’ll soon realize why many lazy summer days in South Carolina are hazy as well. Although this haze is from ozone in the atmosphere and has little to do with acid rain, it is a prime example of how airborne pollutants travel long distances.

The rain falling over the eastern United States and neighboring areas of Canada is 10 to 100 times more acidic than normal. There are some storms in which the rainfall is 1,000 times more acidic. The most cost-effective, and only reliable solution to the acid rain problem, is to control the offending pollutants at their source. The goal is to emit fewer sulfur oxides and nitrogen oxides into the air so that fewer acids form in the atmosphere. Sulfur and nitrogen oxides are formed as a by-product of combustion and are introduced into the air at high altitudes by tall smokestacks. When these oxides mix with water in the air they form acids and are introduced into the ecosystems and fall on buildings when it rains.

DOWN to Earth

***The friends of the Boundary Waters Wilderness is a Minnesota-based environmental organization. They were instrumental in the passage of state acid rain legislation in the early 1980s. These became the strongest acid rain standards in the world.***

***Source: The Information Please Environmental Almanac, 1993***

Plants, animals, ponds and rivers require a delicate balance of pH in order to sustain life. Acid rain can knock that pH out of balance. Buildings and statues are often made of materials such as granite, marble, limestone and copper. Acids cause these materials to deteriorate.

Acid rain varies from one rainfall to the next. In South Carolina you might record a rainfall with a pH of 6.5 one week and it might be 4.2 the next. It should be noted that rainfall is naturally slightly acidic due to the presence of carbon dioxide. However, many factors determine the pH of rain, including the level of airborne pollutants, the type of pollutants and where they came from, how often and how much it has rained since those pollutants were introduced into the atmosphere as well as wind patterns and wind speed.

**Materials**

- pH paper with a color indicator chart, beakers or jars (baby food jars will work, too)

- A variety of substances such as vinegar, ammonia, tap water, rain water, groundwater, soda, lemon juice and baking soda dissolved in water (choose substances with pHs above and below 7)

- For each group, one item for each of the jars: chalk, marble chip, and pennies (because of changes in the copper content of pennies, make sure the pennies used in this lesson were minted prior to 1983)

**Learning Procedure**

1. Share the Background material with the class. Discuss deforestation of the Black Forest in Germany due to acid rain. Note that the South Carolina State House is being renovated. The green dome will be replaced with a new copper dome. Eventually that new dome will turn green. Why? Although the oxidation of copper (turning green) is natural, acid rain hastens this process.

2. Place each substance into a separate jar. Using the pH paper, determine the pH value for each substance. For a control, place plain water in one jar.

3. Place the jars in order or acidity or alkalinity. Note the name of the substance and the pH on each jar.

4. Place in each jar a marble chip, a piece of chalk, and a penny and note your observations.

5. Let the jars sit undisturbed for 48 hours. After 48 hours, look at the items and note any changes in their appearance. Compare the results for the different substances.

6. It may take longer for the substances to affect the penny. Let the substances sit for five days and repeat the observations.

7. The next time it rains, collect some rain water. Do not collect drips from the roof or downspout. Check the pH of the rain water. Where does it fall in comparison to your substances in your jars? Note that the pH of rain may vary widely from rainfall to rainfall.

**Questions for the Class**

1. Which items were the most affected?

2. What was the pH of the substance that affected the items the most?

3. How does adding acidic and alkaline compounds change water quality?

Just do it!

***Note weather patterns that blow into South Carolina. Pay attention to where this "new" wind has been and then look at the economies of the states that are "up-wind" from South Carolina. What kind of pollutants do we add to this wind and send downwind? Who, or what, is downwind from South Carolina?***

**Extension Activities**

1. Have students research the effects of acid rain on well-documented historical structures. Both the U.S. Capitol and the Statue of Liberty have recently undergone extensive renovations to correct damage caused, in part, by acid rain. Remember: due to the natural occurrence of $CO_2$ rainwater is slightly acidic anyway.

2. Perform the following experiment to test various water samples for the presence of carbon dioxide ($CO_2$):

**Materials**

- 200 ml beaker
- 2 eye droppers
- phenolphthalein (Use with caution. This substance is flammable. Keep away from open flame.)
- sodium carbonate ($Na_2CO_3$) solution
- 3 different samples of water labeled A, B, and C
- safety glasses

**Procedure**

1. Pour 100 ml of Water Sample A into a beaker.

2. Add 10 drops of phenolphthalein into the water sample. Swirl GENTLY. Note: if a light pink color appears, wait one-minute. If the pink color remains, the sample has no $CO_2$ gas present. Record this as "zero" on a data chart.

3. If no pink color appears, measure the $CO_2$ present by doing the following:

   A. Using an eye dropper, add sodium carbonate to the solution ONE-DROP-AT-A-TIME. Swirl GENTLY.

   B. Count the number of drops of sodium carbonate needed to form a light pink color in the water sample. Note: A light pink color may form and then disappear in a few seconds. Keep adding drops of sodium carbonate only until the pink color remains.

   C. Record the number of drops used in the data chart.

4. Rinse the beaker well.

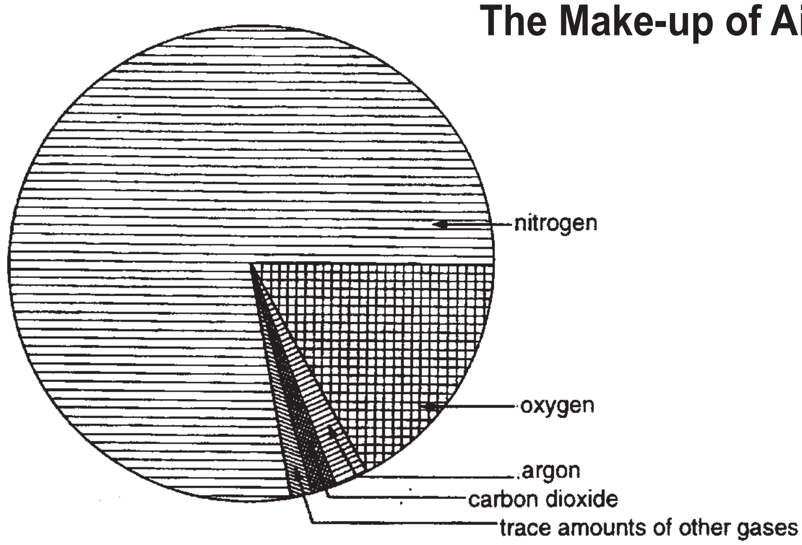
5. Repeat Steps 1 through 4 with Sample B.

6. Repeat Steps 1 through 4 with Sample C.

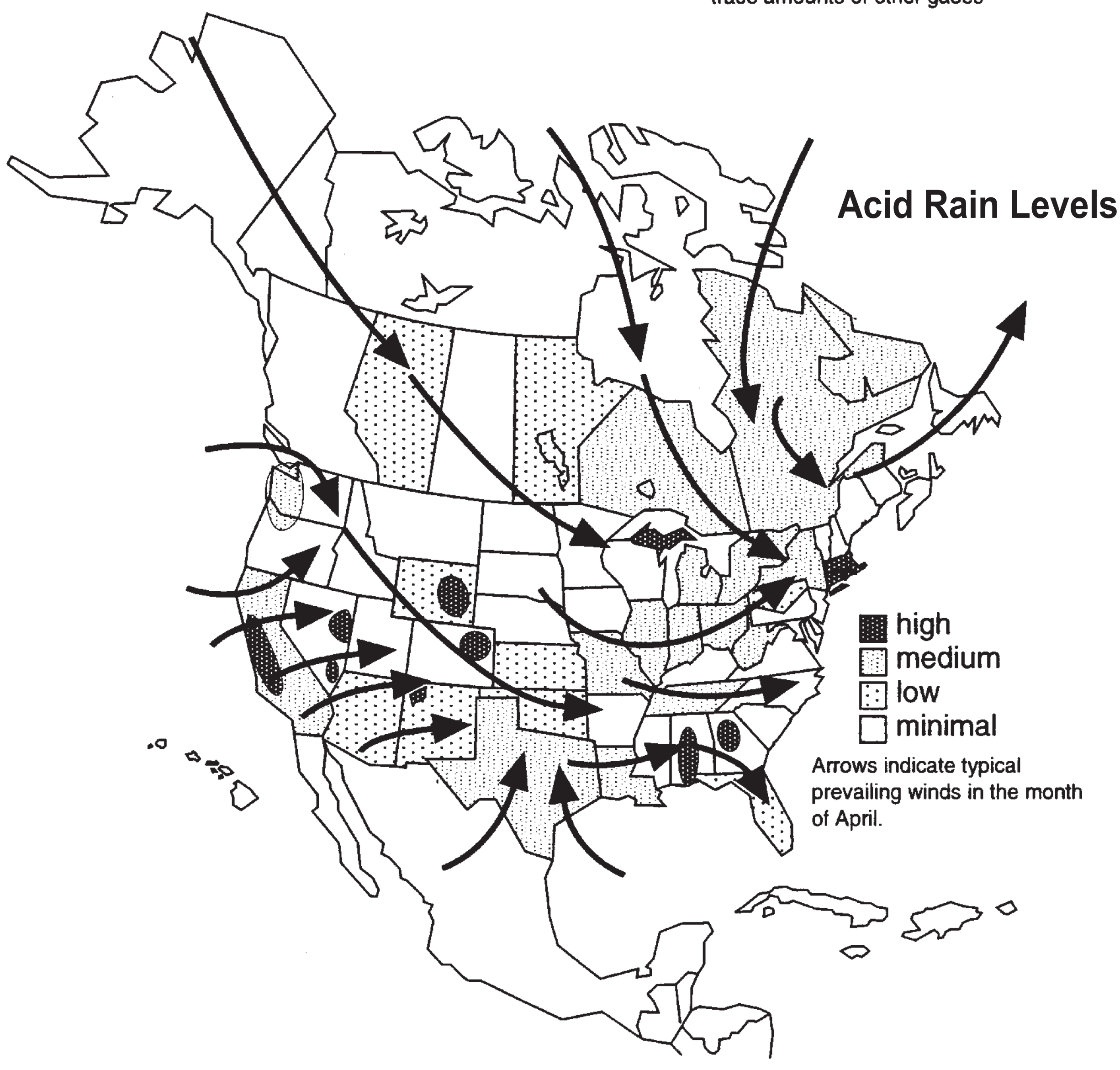
**Ask:** Where does $CO_2$ come from in nature? How does $CO_2$ get into rivers, lakes, etc.? How do lakes, rivers or streams become polluted?

| Water Sample | Data Collection Chart<br>Number of Drops of $NA_2CO_3$ Added |
|---|---|
| A | |
| B | |
| C | |

## The Make-up of Air




## Acid Rain Levels



# The Ozone or the No-Zone?

| Preparation Time: | Easy-to-do | Moderate | Extensive |
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6.AIR.7

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|---|---|
| **Grade:** | 6 – 8 |
| **Focus:** | Ozone |
| **Subject:** | Science, Math, Health |
| **Materials:** | Clean, wide-mouth jars with lids (mayonnaise jars work well), heavy aluminum foil, ice (NOTE: You may wish to work in groups and will need enough materials for each group.) |
| **Teaching Time:** | One class period |
| **Vocabulary:** | Smog, ozone, CFCs |

**Learning Objective**
Students will:

- understand the affect rising pollution levels have on the creation of ozone and on the ozone layer;
- understand the difference between ground-level and stratospheric ozone layers.

**Background**
**Ozone** is a form of oxygen consisting of three oxygen atoms linked together. Ozone is considered to be both helpful and harmful. Chemically, ozone is ozone. In other words, ground-level ozone and stratospheric ozone are the same substance. Whether or not it is helpful or harmful depends on where it is.

"Good" ozone in the upper atmosphere (the "ozone layer") occurs naturally and protects life on earth by filtering out ultraviolet radiation from the sun. Ultraviolet radiation, among other things, produces sun tans, sun burns and, in extreme cases, can lead to skin cancer. The good ozone blocks much of the ultraviolet radiation from entering the atmosphere and reaching the surface of the Earth. Ozone at ground level, "bad ozone," is a noxious pollutant. It is the major component of **smog** and presents this country's most stubborn urban air quality problem. Ozone is a severe irritant. It is responsible for the choking, coughing, and stinging eyes associated with smog. Ozone damages lung tissue, aggravates respiratory disease, and makes people more susceptible to respiratory infections. Children are especially vulnerable to ozone's harmful effects, as are adults with existing respiratory diseases. But even otherwise healthy individuals may experience health problems from breathing ozone-polluted air.

High ozone levels also inhibit plant growth and can cause widespread damage to crops and forests. Unhealthy ozone levels are a problem across the United States, with nearly 100 cities exceeding the U.S. EPA's National Ambient Air Quality Standard. The standard is based on the highest ozone exposure sensitive persons can tolerate. Nine cities, home to 57 million people, are considered "severely" polluted, experiencing peak ozone levels that exceed the standard by 50 percent or more. In South Carolina, all major metropolitan areas meet the federal ozone standards. However, increases in population and motor vehicle travel could lead to problems, especially if automobiles are not properly maintained and factory-installed emissions control equipment does not work properly.

Automobiles are the major source of ozone-producing pollutants. Ozone itself is not produced

**DOWN to Earth**

***Texas releases more toxic materials into the air than any other state - about 170 million pounds. Tennessee is second.***

***Source: The Information Please Environmental Almanac, 1994***

directly by automobiles, but is formed in the atmosphere through a series of chemical reactions involving hydrocarbons, nitrogen oxides, and sunlight. How fast and how much ozone is produced is related to both temperature and intensity of the sunlight. Because of this, high ozone levels usually occur most on hot summer afternoons. In South Carolina, the highest ozone levels generally peak in the mid- to late-afternoons, coinciding with the day's highest temperature. Generally, ozone levels are high between April and October, with May through August being the peak months.

While automobiles are the major contributors of the ozone-producing pollutants, hydrocarbons and nitrogen oxides also come from many industrial and combustion processes. However, in typical urban areas, at least half of those pollutants come from cars, buses, trucks, and off-highway mobile sources such as construction vehicles and boats.

The Clean Air Act of 1970 gives primary responsibility to state and local governments for regulating pollution from power plants, factories, and other "stationary sources." EPA has primary responsibility for regulating "mobile sources," which include cars, trucks, buses, and aircraft.

The EPA vehicle emission control program has achieved considerable success in reducing both nitrogen oxide and hydrocarbon emissions. Cars coming off today's production lines typically emit 76 percent fewer nitrogen oxides and 80 to 90 percent fewer hydrocarbons over their lifetimes than their uncontrolled counterparts of the 1960s. The improvement is a result of strict regulations that require auto manufacturers to develop catalytic converters, systems capable of capturing excess gasoline vapors and cleaning tailpipe emissions.

Ground-level ozone in many cities has decreased with the introduction of unleaded gasoline and as newer cars with improved emission control systems continue to replace older models. Although there has been significant progress since 1970 in reducing emissions per mile traveled, the number of cars on the road — and the miles they travel — has almost doubled in the same time frame.

A second reason that ozone levels remain high is that emission control systems do not always perform as designed over the full useful life of the vehicle. Routine aging and deterioration, poor maintenance, and emission control tampering can increase vehicle emissions. In fact, a major portion of ozone-forming hydrocarbons can be attributed to a relatively small number of "super-dirty" cars whose emission control systems are not working properly.

Unless we dramatically reduce the amount of pollution vehicles actually emit, or drastically cut back on the amount we drive, smog will continue to exist in many cities.

EPA believes controlling ground-level ozone-causing pollutants such as hydrocarbon and nitrogen oxide emissions is the most promising strategy for reducing ozone levels in most urban areas. Toward that end, the federal government will establish more stringent limits on gasoline volatility, control hydrocarbon vapors that evaporate during vehicle refueling, tighten tailpipe emission standards, and require improvements in inspection and maintenance programs. EPA also is developing requirements for "warning systems" on all cars to alert drivers when the emission controls malfunction.

In the most polluted cities, however, these measures will not be sufficient. The only way to ensure healthy air is to markedly reduce our use of cars or to switch to fuels that are inherently cleaner than conventional gasoline. Using these alternative fuels means substituting methanol, ethanol, or natural gas for conventional gasoline. Using electricity would result in somewhat greater reductions in ozone-forming hydrocarbons; propane, in somewhat smaller reductions; and reformulated gasoline, in considerably smaller reductions, relative to methanol, ethanol, or natural gas fuel.

Stratospheric ozone, on the other hand, is yet another tale. The so-called "good" ozone exists 12 to 30 miles (19 to 48 kilometers) above the earth and it resides in the stratosphere. In the upper levels of the atmosphere, ozone forms a protective layer that blocks ultraviolet rays from the sun.

This protective layer of “good” ozone is being depleted by a family of chemical compounds known as chlorofluorocarbons, or **CFC**s. CFCs are very stable compounds that last a long time. Once they are released into the atmosphere, CFCs remain CFCs and don’t easily break down into their component elements, two of which are chlorine and fluorine. CFCs drift into the upper atmosphere — it can take decades for this to happen — where the CFCs are broken down by the sun’s ultraviolet rays, releasing the chlorine and the fluorine which then destroys the protective ozone layer.

Any ozone-depleting material released today will destroy the ozone layer many years from now. One CFC-molecule can destroy 100,000 ozone molecules. It’s easy to see why ozone is disappearing much faster than nature replaces it.

CFCs, under the Clean Air Act of 1990, are being phased out of use in aerosol cans, air conditioners and refrigerators. It is currently illegal to release all refrigerants into the atmosphere. Other ozone-depleting substances include solvent cleaning products, refrigeration and air conditioning fluids, foam products such as polystyrene, aerosols, and other products such as halon which is used in some fire-suppressant systems.

**Learning Procedure**

1. Explain that the class will be making artificial smog in a jar. Remind them that this is only a demonstration, and they will only be replicating the *appearance* of smog, not the actual make-up of smog or its effects. Remind them that smog is *not* smoky fog.

2. Cut a strip of paper about 6 inches x 2 inches. Fold it in half and twist it into a rope-like shape.

3. On the top of the jar, form a snug lid for the jar using aluminum foil. Make a small indentation to keep the ice cubes from sliding off. Carefully remove the foil lid and set it aside.

4. Put a little water in the jar and swirl it around to wet the inside of the jar. Pour off any excess water.

5. Light the paper and drop it and the match into the jar. Quickly put the foil lid in the jar and seal it tightly. Place the ice on the lid to make it cold so that the water vapor in the jar will condense. This step must be done very quickly so the students may need some help.

6. Have the students record their observations. Does this look like real smog? What is the “smog” in the jar made of? (water vapor, soot particles, carbon dioxide and other vapors)

**Questions for the Class**

1. Ask students to identify trips they themselves make in cars that might be unnecessary, trips that could be eliminated, or those which could be accomplished by other means of transportation.

2. How does urban growth affect air pollution?-Housing patterns? Where people live in relation to where they work, shop, go to school?

3. What are the advantages and disadvantages of mass transit? Carpooling? Taking the school bus?

4. How many cars are registered in your city? County? South Carolina? The South Carolina Department of Transportation can provide this information and may be a good source for a classroom speaker.

5. What is a catalytic converter? How does it change auto emissions? A professional mechanic could bring a catalytic converter to class and discuss its operation.

6. South Carolina recently changed the law requiring annual safety inspections for cars. Some states still require safety inspections as well as annual emission inspections. Although we do not require emission inspections in this state and since we no longer require safety inspections, will this affect air quality in South Carolina? In the United States?

7. What are some of the alternatives to automobile transportation? *(Mass transit, bicycles, etc.)*

**Extension Activity**
Some fuels are inherently cleaner than gasoline because they emit fewer nitrogen oxides or hydrocarbons, and because the hydrocarbons they do emit are less likely to react in the atmosphere to form ozone. Have students research and write a report on one or more of the following alternative fuels:

- **ALCOHOLS:** Methanol (made from natural gas, coal, or biomass) and ethanol (made from grains or sugar) are high-octane liquid fuels. Cars designed to run on pure alcohol fuels have the potential to emit 80 to 90 percent fewer reactive hydrocarbons than advanced-technology gasoline cars.

- **ELECTRICITY:** Battery-powered cars have the potential for zero tailpipe and evaporative hydrocarbon and nitrogen oxide emissions, although we must still account for power plant emissions. Today's electric vehicle technology is limited, but promising recent developments may lead to more widespread use in the future.

- **NATURAL GAS:** Compressed natural gas is also an excellent automotive fuel, particularly for fleet vehicles where long driving range is not important. Natural gas vehicles have the potential to emit 85 to 95 percent fewer reactive hydrocarbons than advanced-technology gasoline vehicles.

- **LIQUID PETROLEUM GAS (PROPANE):** Propane is a by-product of petroleum refining and natural gas production. Propane vehicles emit considerably less ozone-forming hydrocarbons than do vehicles fueled with conventional gasoline.

- **REFORMULATED GASOLINE:** The petroleum industry is studying ways to change refinery procedures to make a cleaner-burning gasoline. A number of "clean" gasolines have recently been introduced into the marketplace, and research is continuing to develop even cleaner fuels. Reformulated gasolines are capable of reducing hydrocarbon emissions by at least 15 percent.

Just do it!

***Check your home and school fire extinguishers. Look for halon chemicals. Halon is an ozone-depleter and, even though you may not use your fire extinguisher, halon can leak into the air. If your fire extinguisher does contain halon, have it replaced with a safer chemical fire extinguisher. Check your telephone book's Yellow Pages for a fire extinguisher supply company. Call for advice on disposal of halon-based fire extinguishers as well as what kind to get that will be kind to the ozone.***

# Feelin' Alright?

| Preparation Time: | **Easy-to-do** | Moderate | Extensive |
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6.AIR.8

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| **Grade:** | 6 – 8 |
| **Focus:** | Health effects of air pollution |
| **Subject:** | Science, Health, Geography |
| **Materials:** | Transparency, environmental health care professional (optional) |
| **Teaching Time:** | One class period, out-of-class research |
| **Vocabulary:** | Particulates |

**Learning Objective**
Students will gain knowledge of how pollutants affect our health.

**Background**
Different pollutants affect our health in very specific ways. In fact, physical symptoms are often a good clue to identifying which pollutants are out there bothering people.

Prolonged exposure to these compounds can affect people in predictable ways. According to the U.S. EPA, carbon monoxide causes headaches, blurred vision and slow reflexes. Lead causes learning difficulties and alters kidney function and blood chemistry. Sulfur dioxide will cause heart and lung problems and can also harm vegetation and metals. Particulates, dust, soot, etc., can irritate the throat and cause heart and lung problems as well.

Nitrogen dioxide may cause increased respiratory illness such as chest colds and coughing, and may cause increased breathing difficulties in asthmatics. Ozone causes choking and coughing as well as irritates the eyes throat and nose.

**Learning Procedure**

1. Share the background material and use the transparency (included) to discuss the health effects of these pollutants.

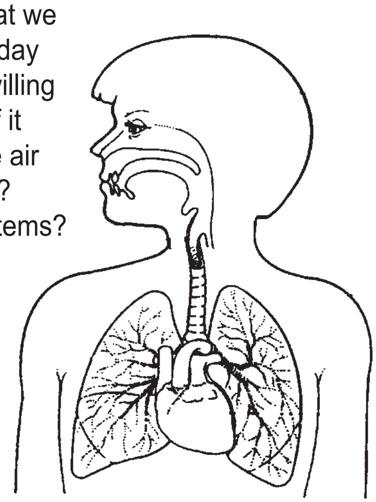
2. Assign to the students the different pollutants and have them research their sources, which areas of the country/world have the highest concentrations, do areas without any immediate sources of these pollutants have anything to worry about?

**Questions for the Class**

1. Are some of these air pollutants found indoors? Outdoors?

2. How would weather affect the concentration of air pollution?

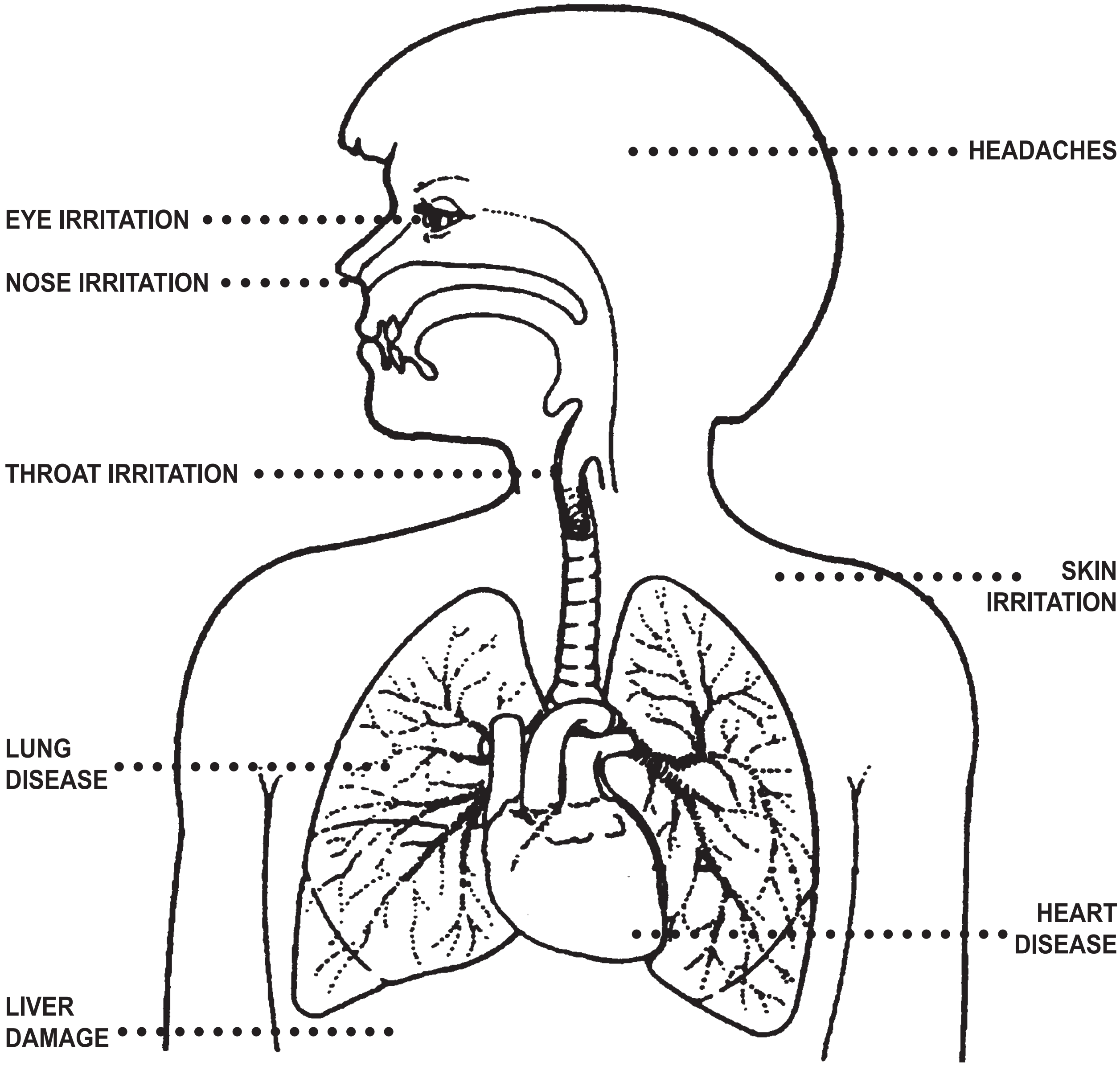
3. Which items that we deal with everyday would you be willing to live without if it would eliminate air pollution? Cars? Manufactured items? Household products?



DOWN to Earth

***The number of vehicles in use around the world is expected to double to around 1 billion within the next 40 years. Much of this growth will take place in developing countries where the automobile population is expected to increase by more than 20 percent by the end of the century.***
***The Information Please Environmental Almanac, 1993***

# Air Pollution and You




**Airborne Particulates**
- irritates your throat
- causes heart and lung problems

**Carbon Monoxide**
- causes headaches
- causes slow reflexes
- causes blurred vision

**Ozone**
- irritates your eyes, nose and throat
- causes choking and coughing

**Nitrogen Dioxide**
- increases respiratory illness such as colds
- increases breathing difficulties in asthmatics

**Sulfur Dioxide**
- causes heart & lung problems
- harms vegetation and metals

**Lead**
- causes learning problems
- alters kidney function
- alters blood chemistry

# The Greenhouse Effect

| Preparation Time: | Easy-to-do | **Moderate** | Extensive |
|---|---|---|---|

6.AIR/EPA.1

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|---|---|
| **Grade:** | 5 – 7 |
| **Focus:** | Greenhouse Effect, air pollution |
| **Subject:** | Science |
| **Materials:** | Two clean, dry, wide-mouth glass jars with lids (like mayonnaise jars), heavy aluminum foil, a piece of dark cloth or construction paper, stop watch or watch with a second hand, two identical thermometers that fit into the jars (meat thermometers work well), paper, pencils |
| **Teaching Time:** | 20 minutes (with possible extensions) |
| **Vocabulary:** | Albedo, carbon dioxide, chlorofluorocarbons, Greenhouse Effect, greenhouse gas, methane, nitrogen oxides |

**Learning Objectives**
Students will:

- understand that the atmosphere traps heat and makes the surface of the Earth warm enough for life;
- recognize that air pollution can cause a rise in temperature and ecological decline;
- recognize that human activities can cause air pollution by observing, comparing, interpreting text results, drawing conclusions.

NOTE TO TEACHERS: This activity introduces the concepts of climate change and the “greenhouse effect.” While global warming may sound great, thinking through the possible effects upon plants, sea levels, and the world’s food supply may cause the students to better appreciate how complex a role the atmosphere has in our lives.

**Background**
The greenhouse effect is a term scientists use to describe the trapping of heat on the surface of the Earth by the atmosphere, a normal atmospheric occurrence. As a result of this, the Earth’s surface is about 53°F (12°C) warmer than it would be without this trapping. This effect is magnified by certain greenhouse gases in the atmosphere, most notably carbon dioxide, methane, nitrogen oxides, and chlorofluorocarbons (CFCs). Methane is a product of natural decay from living (or once-living) things; nitrogen oxides are generally a result of man-made burning and automobile and similar internal-combustion engines; and CFCs are a class of chemicals used often in air conditioners, refrigerators, and as the pressurizing gas in aerosol spray cans. While all of these pollutants contribute to air pollution, and contribute to the green-house effect, carbon dioxide is the most important greenhouse gas.

Scientists believe that concentrations of greenhouse gases in the atmosphere will double over the next hundred years, producing average temperature rises of about 8 to 10°+F (4 to 6°+C). While most scientists believe that the greenhouse effect will gradually warm up the Earth’s climate, there are some who believe that increased cloud cover will eventually reflect more sunlight away from the Earth and lower the average temperature. This increased reflectivity is called the Earth’s albedo. (See reading material on “Air Pollution” and “The Greenhouse Effect” in the Resource Section.)

**Learning Procedure**

1. Divide the class into two work groups. Give each group one of the jars. Have each group put a piece of dark cloth or paper into their jar.

Have them put a thermometer in each jar so that the scale can be read through the side. Have one group screw the cover onto their jar. Have the other group leave their jar open.

2. Have the groups place the jars, on their sides, in sunshine so that their bottoms face the sun.

3. Instruct each group to watch the thermometers and have one person from the group record the temperature shown in their jar every minute. Instruct the group with the closed jar to announce when the thermometer in their jar levels off or reaches $140^0$F ($60^0$C). Stop the experiment at that point.

4. Have students discuss the following questions:
   - In which jar does the temperature rise fastest?
   - How much faster did it rise? Why?
   - How is this like a greenhouse?
   - How is this like the real world's atmosphere?
   - What was the role of the dark cloth in the jars?

**Extension Activities**

Have students wrap one of the jars with aluminum foil, leaving a clear area away from the sun to read the thermometer. Repeat the experiment, and compare the times to reach $140^0$F ($60^0$C). Discuss why it took longer.

Have students try the experiment on a cloudy day. Discuss the difference in results. Have them try the experiment without the dark cloths and discuss the difference in results.

**Suggested Reading**

Berreby, David. "The Parasol Effect." *Discover,* 14 (July 1993) p. 44.

Bright, Michael. *The Greenhouse Effect.* New York: Gloucester Press (1991).

Gay, Kathlyn. *Ozone.* New York, NY: Franklin Watts (1989).

Horgan, J. "Greenhouse America." *Scientific American* (January 1989) p.20.

Jones, P. D., and T. M. L. Wigley. "Global Warming Trends." *Scientific American* (August 1990) p. 89.

Nardo, Don. *Ozone.* San Diego, CA: Lucent Books (1991).

Schneider, S. H. "The Changing Climate." *Scientific American* (September 1989) p. 89.

*This lesson was adapted from the EPA publication Project A.I.R.E. – Air Information Resources for Education (K-12).*

# Read My Data

| Preparation Time: | Easy-to-do | Moderate | Extensive |
|---|---|---|---|



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|---|---|
| **Grade:** | 5 – 8 |
| **Focus:** | Air pollution, The Clean Air Act |
| **Subject:** | Science, Social Studies, Math |
| **Materials:** | Paper, pencil, two worksheets (included) |
| **Teaching Time:** | One class period |
| **Vocabulary:** | Air quality monitoring, ambient air, data, pollutant, standards, trend |

**Learning Objectives**
Students will:

- understand how data is collected and analyzed;
- recognize air pollutants the government requires to be monitored.

NOTE TO TEACHERS: Most environmental decisions and regulations are based upon large quantities of numerical data and trends. This exercise introduces students to the fundamentals of reading and analyzing data and extracting comparisons and averages. It can be delivered by the teacher or a guest presenter, or by both together.

**Background**
No matter where you live, but especially in urban areas, each breath you take contains gases or particles that may be unhealthy. We know this from the analysis of air quality data from around the country. We also know that much of the air pollution is invisible and cannot be detected by human senses. Realistically, in our industrial society, it is not practical to expect that air pollutants can be eliminated totally anywhere, so it becomes important to determine what "acceptable" concentrations will be allowed, and equally important to monitor ambient air quality so that these "acceptable" limits are not exceeded. Most air quality monitoring is done automatically by specialized equipment located strategically throughout the country. These monitoring stations collect vast quantities of data and create a record of the concentrations and durations of specific pollutants. The Clean Air Act establishes certain "standards," or acceptable levels, for various "criteria" pollutants. Most laws and regulations have separate standards for averaged concentrations over certain short- and long-terms (such as maximum 8-hour average concentrations). The Clean Air Act establishes National Ambient Air Quality Standards for six criteria pollutants: carbon monoxide, sulfur dioxide, nitrogen oxides, ozone, particulate matter, and lead. The short-term National Ambient Air Quality Standards (NAAQS) for several pollutants are shown on the accompanying table.

This exercise will look at concentrations for the first four pollutants in several cities around the country. Just how clean is your air? You could guess—but check the accompanying data and find out. (See reading materials on "The Clean Air Act," and "Air Pollution" in the Resource Section.)

**Learning Procedure**

1. Write "1 ppm" on the chalkboard, and next to it write the fraction:

   $$\frac{1}{1,000,000}$$

   Explain that "ppm" means "parts per million" and is similar to "percent" in that "percent" means "parts per hundred." Explain that, like "percent," ppm has no units or dimensions (such as grams or cubic meters). Challenge the class to state which quantity is smaller, 1 ppm or 1 percent. For older students, ask them to compute how much smaller 1 ppm is than 1 percent. Point out that since there are 10,000 “hundreds” in a million, 1 ppm must be 10,000 times smaller than one percent.

2. Using Student Worksheet 1, explain to the class what the numbers represent and ask the students to answer the questions. (For more advanced students, request the answers in quantitative terms.)

3. Using Student Worksheet 2, direct the students to calculate the percentage change in pollutant concentrations from 1975 to 1991 for the listed pollutants. Call students’ attention to the fact that two of the six pollutants have units of mg/ m 3, which means micrograms per cubic meter, while the other four pollutants have units of ppm, or parts per million. Explain to them that both represent concentrations of pollutants in the air. The four ppm pollutants are all gases, and most fluids (gases and liquids) normally have concentrations expressed as milliliters per liters (part per thousand) or microliters per liter (parts per million). Lead and particulates are solids, and their density cannot be arbitrarily established in relation to air. Therefore, their concentrations are normally expressed as a unit of weight (mass) per volume of air. The difference in the units of measure does not affect the calculation of percentage change.

4. Ask the students to identify significant changes. Have them speculate as to why the changes might have occurred. Discuss their answers with the guest speaker (if applicable).

5. Point out to the students that the standards are very different from each other. Ozone’s permissible level, for instance, is 75 times lower than that of carbon monoxide. Ask the class to speculate why the standards may be different for different substances. Explain that the human health tolerances are different for each pollutant and each pollutant may cause different health effects. The regulations account for these differences.

**Extension Activity**
Call SCDHEC – Bureau of Air Quality for information about where to obtain similar data for your geographic location. Conduct a similar analysis.

**Suggested Reading**

Baines, John. *Conserving Our World, Conserving the Atmosphere.* Austin, TX: Steck-Vaughn Company (1990).

Gay, Kathlyn. *Acid Rain.* New York: Franklin Watts (1983).

*Pollution (Science Kit).* Delta Education (1990).

*This lesson was adapted from the EPA publication Project A.I.R.E. – Air Information Resources for Education (K-12).*

# Read My Data: Major Air Pollutants for Selected Cities in the United State, 1991

| CITY | CARBON MONOXIDE* | OZONE** | SULFUR DIOXIDE*** | NITROGEN OXIDES*** |
|---|---|---|---|---|
| **National Standards** | **9 ppm** | **0.12 ppm** | **0.030 ppm** | **0.053 ppm** |
| Atlanta | 7 | 0.13 | 0.008 | 0.025 |
| Boston | 4 | 0.13 | 0.012 | 0.035 |
| Chicago | 6 | 0.13 | 0.019 | 0.032 |
| Detroit | 8 | 0.13 | 0.012 | 0.022 |
| Houston | 7 | 0.20 | 0.007 | 0.028 |
| Indianapolis | 6 | 0.11 | 0.012 | 0.018 |
| Los Angeles | 16 | 0.31 | 0.005 | 0.055 |
| New Orleans | 4 | 0.11 | 0.005 | 0.019 |
| New York City | 10 | 0.18 | 0.018 | 0.047 |
| Pittsburgh | 6 | 0.12 | 0.024 | 0.031 |
| San Francisco | 8 | 0.07 | 0.002 | 0.031 |
| St. Louis | 7 | 0.12 | 0.016 | 0.026 |

*Second highest 8-hour average **Second highest 1-hour average ***Yearly average

1. Which cities have carbon monoxide levels above the National Standards? Express the answers in percentages over or under the limit.

   For example, New York's 10 ppm is

   $$(10 - 9) \div 9 = 1/9 = 0.111 = 11\% \text{ over the National Standard}$$
   $$(\text{data} - \text{permissible limit}) \div (\text{permissible limit}) = ? \times 100 = \% \text{ over limit}$$

2. Speculate why any of the cities would exceed the permissible limits.

3. Do the same for the other three air pollutants.

# Read My Data: Changes in Average Concentration Pollutants in the U.S., 1975-91

| POLLUTANT | 1975 | 1991 | % CHANGE |
|---|---|---|---|
| Carbon Monoxide | 10 ppm | 6 ppm | _______ |
| Lead | 0.68 $\mu g/m^3$ | 0.048 $\mu g/m^3$ | _______ |
| Nitrogen Oxides | 0.021 ppm | 0.021 ppm | _______ |
| Ozone | 0.147 ppm | 0.115 ppm | _______ |
| Particulates | 63 $\mu g/m^3$ | 47 $\mu g/m^3$ | _______ |
| Sulfur Dioxide | 0.0132 ppm | 0.0075 ppm | _______ |

Show increase with a plus (+) sign and decrease with a minus (-) sign in front of the percentage.

SOURCE: United States Environmental Protection Agency, *National Air Quality and Emissions Trends Reports,* 1981 and 1991.

Calculate the percentage change for each pollutant. To do this, subtract the 1991 value from the 1975 value (to get the actual difference), then divide that answer by the 1975 value to get the percentage change since 1975.

1. What was the percentage of change (either increase or decrease) in each pollutant for each city from 1975 to 1991.

   For example, sulfur dioxide went down by 43 percent:

   $$(0.0132 - 0.0075) \div 0.0132 = 0.4318 \times 100 = 43.18\% \text{ (rounded to 43\%)}$$

   $$(1975 \text{ value} - 1991 \text{ value}) \div (1975 \text{ value}) = ? \times 100 = \% \text{ change}$$

   Round your answers to whole percentages.

2. Did any pollutant concentrations go up?

3. Which pollutant changed the most?